Final Report

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Title: GaN MISFETs
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Long term goals: Microwave signal amplification at high power levels exceeding those achieved with currently available GaN Heterostructure Field Effect Transistor Technology

Objectives:

Conduct experimental and theoretical studies to demonstrate and analyze the advantages offered by AlN/GaN MISFETs:

- MOCVD Growth of high-quality AlN/GaN heterostructures
- Simulate AlN/GaN MIS structures and MISFETs
- Develop high-power AlN/GaN MISFETs and Amplifiers
- Characterize DC, low- and high-frequency, and power performance of AlN/GaN MISFETs

Approach:

- Evaluate the crystalline quality of AlN/GaN heterostructures and in particular AlN through XRD
- Determine the electrical properties of MISFETs through Hall characterization and evaluate optimum designs for normal and inverted AlN/GaN heterostructures
- Study the low-frequency properties of AlN/GaN MISFETs and determine interface state properties and dispersion effects and their impact on small and large-signal device properties
- Fabricate micron and submicron AlN/GaN MISFETs devices
- Optimize the DC, small-signal, and power characteristics of AlN/GaN MISFETs through simulation and experimentation ⇒ determine optimum MISFET layer structures
- Design, fabricate, and characterize high-power MISFET amplifiers

Work Completed:

- Evaluated the crystalline quality of AlN/GaN heterostructures and in particular AlN through XRD
- Determined the electrical properties of MISFETs through Hall characterization
- Determined the interface state properties of AlN/GaN MISFETs
- Fabricated micron AlN/GaN MISFETs devices
- Simulated the DC characteristics of AlN/GaN MISFETs

Results:

- XRD of MISFET structure shows distinctive AlN peak (d_{AlN} = 12nm) indicating good crystalline quality
- AlN thickness was varied between 5 and 18nm to maximize electron mobility
- Hall mobility of overall MISFET (GaN channel and thin AlN barrier) structure increases with decreasing AlN thickness up to $\mu = 320 cm^2/(Vs)$ for 11nm AlN
- The necessary process for AlN/GaN MISFETs was developed and applied to heterostructures grown by MOCVD
- The DC, low-frequency, high-frequency and small-signal characteristics of AlN/GaN MISFETs were studied experimentally and the results demonstrate good electrical performance.

- AlN/GaN MISFETs 2μm-long gates demonstrated I_{DSS} of 700mA/mm and extrinsic g_m of 136mS/mm
- AlN/GaN MIS demonstrate good C-V characteristics corresponding to low interface states density of $\sim 10^{11} cm^{-2} eV^{-1}$

- Modeling and characterization confirms extremely low heterostructure interface density

Impact/Applications:

- Development of high power III-V Nitride MISFETs operating at high frequency responds to the needs of future generation multifunctional electromagnetic systems envisioned by the Navy and DoD
- The devices studied under this program will allow to increase the performance of radar, electronic warfare and communications systems through improved power characteristics at high frequencies.

Transitions: N/A

Related Projects: N/A

References: N/A

Publications (Names of books, chapters, or significant papers as a result of award):

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XRD characterization of MISFET structures showed distinctive AlN peaks (dAlN = 12nm) indicating good crystalline quality.The AlN thickness of the I-layer was varied between 5 and 18nm to maximize the electron mobility. The Hall mobility of the overall MISFET (GaN channel and thin AlN barrier) structure was found to increase with decreasing AlN thickness up to m = 320cm2/(Vs) for 11nm AlN. The necessary process for AlN/GaN MISFETs was developed and applied to heterostructures grown by MOCVD. The DC, low-frequency, high-frequency and small-signal characteristics of AlN/GaN MISFETs were studied experimentally and the results demonstrate good electrical performance. In particular, AlN/GaN MISFETs 2μm-long gates demonstrated IDSS of 700mA/mm and extrinsic gm of 136mS/mm. Moreover, AlN/GaN MIS demonstrate good C-V characteristics corresponding to low interface states density of ~1011cm-2eV-1

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